LPR Bathymetry Analyses based on 2007, 2008, 2010 & 2011 multi-beam surveys

CPG-EPA Collaboration Meeting
June 12, 2012

Main Findings and Observations

- All bathymetry evolution is aligned with system understanding (erosion/deposition in relation to hydrograph)
- River bed is generally stable even at very high flows
- Localized effects (bridges, shipping etc.) – sub-grid effects important, but not accounted for in model
- Above RM 8 changes in bed forms - sends coarser material downstream, armoring legacy sediments
- Bathymetry analysis agrees with TSS results

Take-Away Message for CSM

- Quantify the response of the river in terms of the hydrograph and the response of the bed
- Significant contribution of local (cyclical) effects supports strategy of targeted remediation
- Model and bathymetric analysis allow a detailed design of a targeted remedy

set-up of this presentation

- What did we do?
- Project relevance: Why did we do this?
- Discussion of relevant topics from the analysis following main conclusions

what did we do?

- Upload 5×5 ft resolution multi-beams 2007, 2008, 2010, 2011_{lim} and 2011 into Open Earth*
- Construct differential-bathy maps
- Analyze bed evolution at variety of scales
- Made a start with river-covering sediment mass balance
- Compare bathy-data with TSS & other data

*Open Earth is powerful data analysis package integrated with Google Earth facilities

project relevance

- Assess river stability at frequent and extreme events (Irene)
- Differentiate between local scour and bed erosion
- Provide input for targeted remediation
- Provide data for model calibration and interpretation
- Provide data for system understanding
- Contribute to another line of evidence

Relevant Topics

1. Correction of 2008 multi beam survey
2. Evolution has to be assessed in conjunction with hydrograph
3. Interpretation of bed level changes in the LPR
4. Local scour and Infill
5. Quantification of the transition between hydro-sedimentological regimes I, II & III
6. Consistency of bathy evolutions with other data
7. Sand transport in upper reaches

Relevant Topics

1. Correction of 2008 multi beam survey

correction of 2008 multi-beam

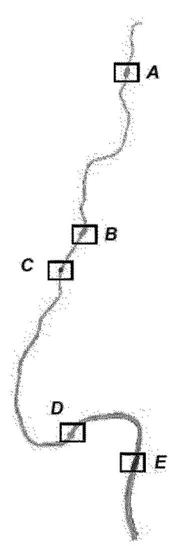
Original 2008 data do not make sense; correction based on:

- Comparison of reference points (rock outcrop)
- Comparison of multiple cross sections
- Implications for overall mass balance (compared to other years)
- Comparison with TSS data

2008 data seem ~0.3 ft too low (systematically), and have been corrected based on the previous analyses

comparison of reference points multi-beam 2007 & 2008

Figure 6: Segments of the Passaic River where 2008 and 2007 multibeam bathymetry data were compared based on average depth in a 3 ft by 3 ft grid spacing.



from report multi-beam & side-scan sonar

comparison of reference points multi-beam 2007 & 2008

Likely error in 2008 survey

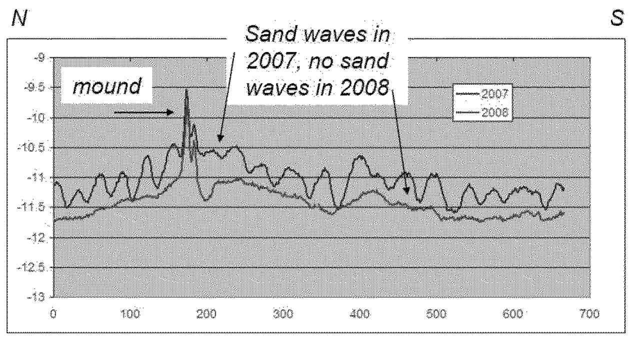


Figure 7c:

River Segment A (RM13.6) Transect bathymetry in 2007 and 2008 and change (2008-2007).

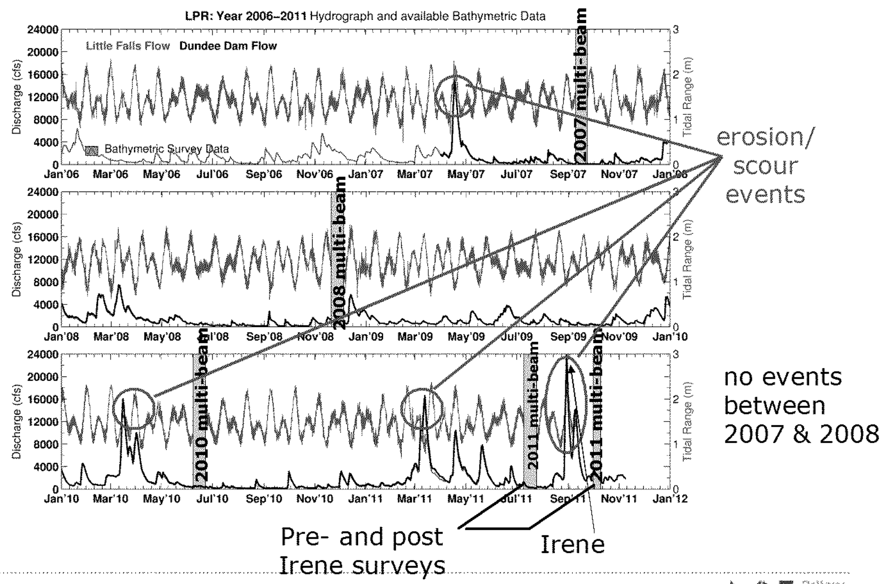
Depths (x-axis) and Distances (y-axis) in Feet

Height of rock outcrop and other reference points in bathymetry suggest systematic error of about -0.3 ft in 2008 data

Relevant Topics

1. Correction of 2008 multi beam survey
2. Evolution has to be assessed in conjunction with hydrograph

hydrograph during multi-beams



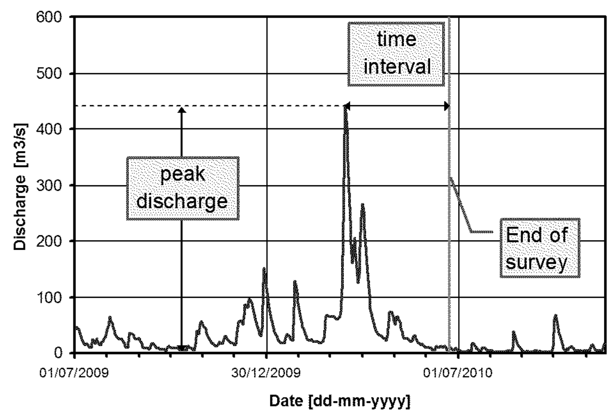
LPR extreme flows

- Extreme analysis at Little Falls (1891 to 2005) by EPA (Appendix G, Draft FFS)
  - 1-year 6,200
  - 5-year 9,968
  - 10-year 12,219
  - 25-year 15,280
  - 50-year 17,465
  - 100-year 19,808
- Since 2005 we have had 1-10Yr, 2-25Yr and 1-100Yr. Irene was the second largest value in the USGS record since 1900 at Little Falls
  - Oct 10, 1903 – 31,700 cfs
  - Aug 30, 2011 – 20,800 cfs
  - Jul 23, 1945 – 19,500 cfs

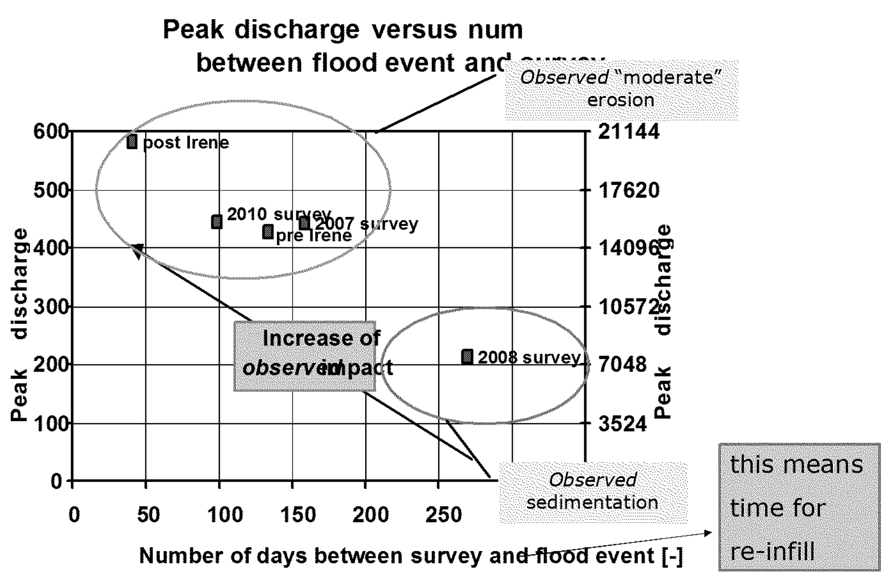
river floods: *observed* impact

- *Observed* effect depends on magnitude of event and time interval between survey and river flood

Passaic River discharge at Little Falls NJ



phasing of surveys w.r.t. hydrograph



Relevant Topics

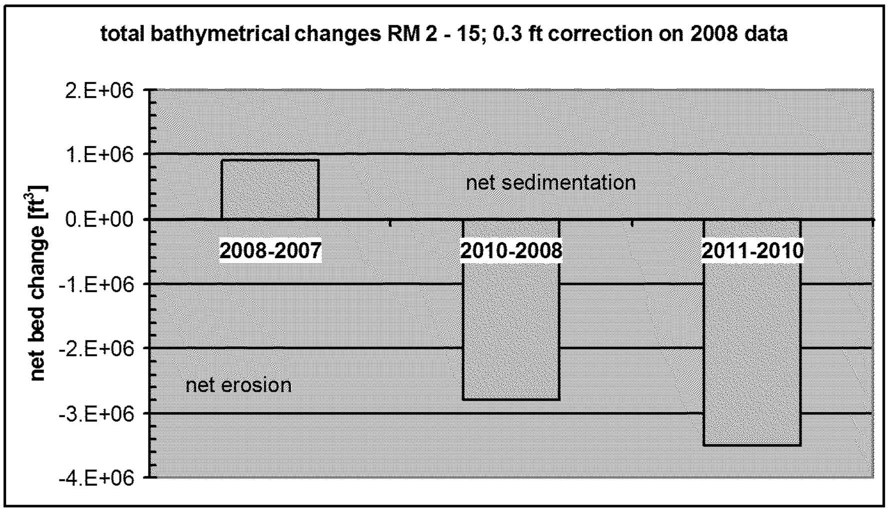
1. Correction of 2008 multi beam survey
2. Evolution has to be assessed in conjunction with hydrograph
3. Interpretation of bed level changes in the LPR

overall mass balance

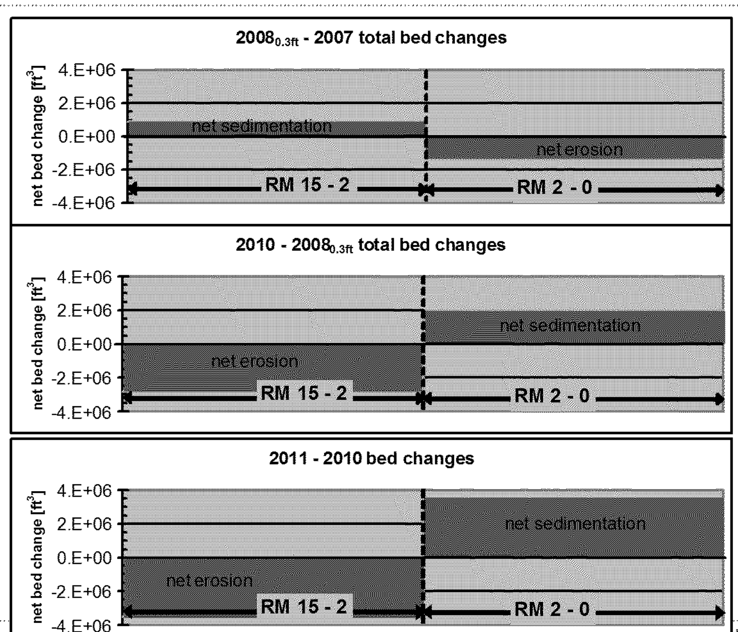
- apply 2008 bathy correction
- subtract various bathymetries and integrate over length of river
- note that multi-beam soundings cannot account for shallow areas

LPR/NB Modeling Program preliminary results – subject to review and revision Deltares

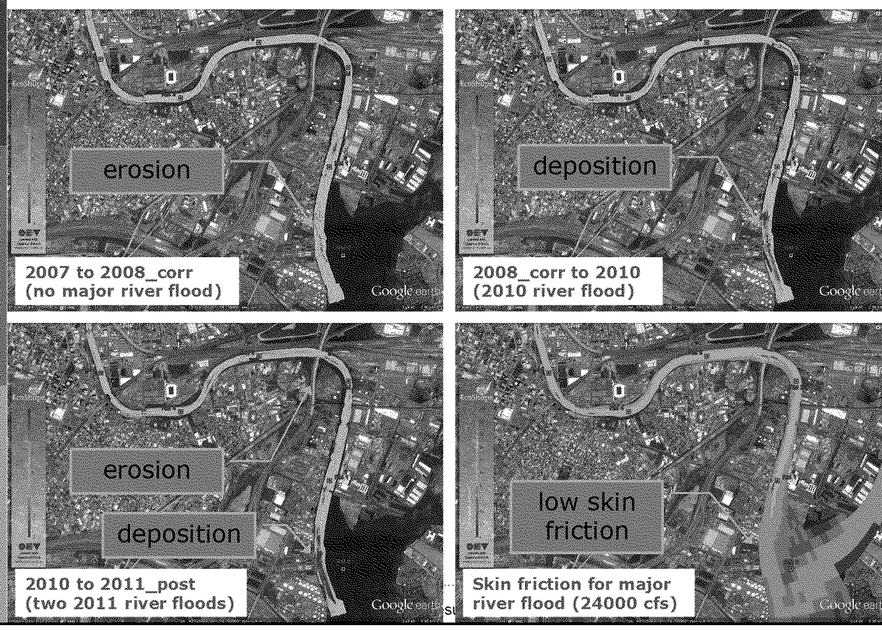
overall mass balance agrees with hydrograph



overall mass balance including LPR mouth



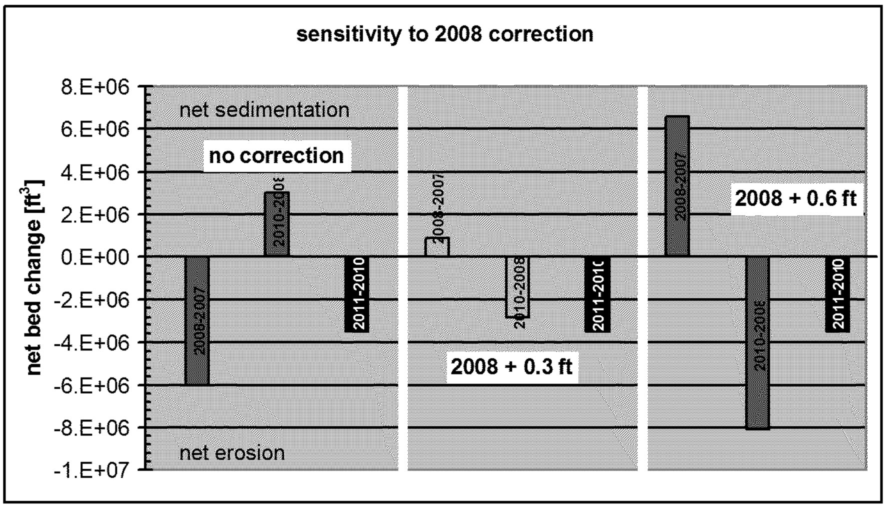
erosion-deposition: RM-0.5 to RM 5



Relevant Topics

1. Correction of 2008 multi beam survey – effect on mass balance
2. Evolution has to be assessed in conjunction with hydrograph
3. Interpretation of bed level changes in the LPR

2008 bathy correction – mass balance



Relevant Topics

1. Correction of 2008 multi beam survey
2. Evolution has to be assessed in conjunction with hydrograph
3. Interpretation of bed level changes in the LPR
4. Local scour and Infill

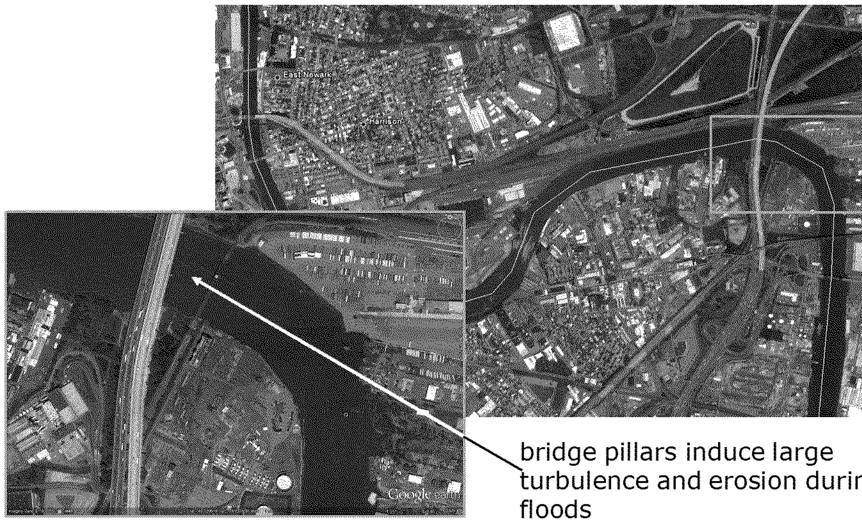
local scour and infill

- These sub-grid effects may be most important findings of bathymetrical analyses in relation to targeted remediation
- Few examples are presented – there are many more
- Large mass of mobile sediments may be characterized by cyclical scour and infill
- Such cyclical behavior does not affect stability of legacy sediments
- We are quantifying ratio scour/infill to erosion/sedimentation (in progress)
- Scour/infill are sub-grid effects for numerical model - this should be accounted for in interpretation of model results

Types of local effects:

Effect of Bridge Pillars

RM 2.0 – 2.5

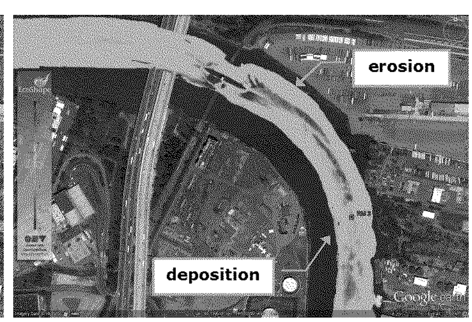


bridge pillars induce large turbulence and erosion during floods

bed level changes RM 2 – 2.5

seems cyclic

2007 to 2008_corr
(no major river flood)

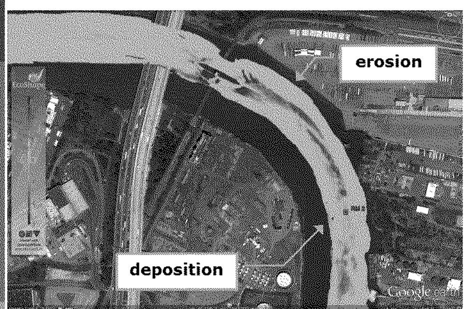


2008_corr to 2010
(2010 river flood)

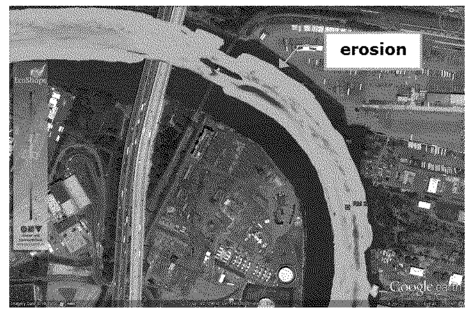
eroded sediment from around bridge should be fairly coarse, as deposited downstream of scour under high flows

bed level changes RM 2 – 2.5

from modeling point of view, these are sub-grid effects:
- model resolution (grid size)
- turbulence modeling around obstructions



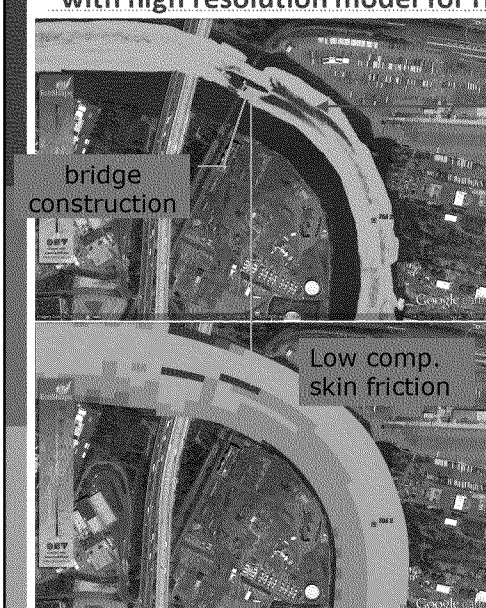
2008_corr to 2010
(2010 river flood)



2010 to 2011_post
(two 2011 river floods)

earlier deposits from 2010 flood have now been flushed out of the river

erosion (2008 to 2011_post Irene) and skin friction (computed with high resolution model for river flood of 24000 cfs)



... resulting in downstream erosion

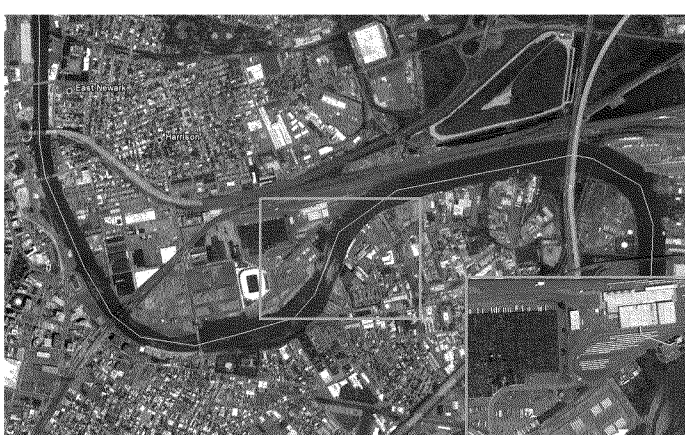
... but turbulence generated and advected

Thus: computed local bed shear stresses may not explain local erosion = sub-grid effect

Types of local effects:

Effect of Bank Irregularities

~RM 3.5 – 4

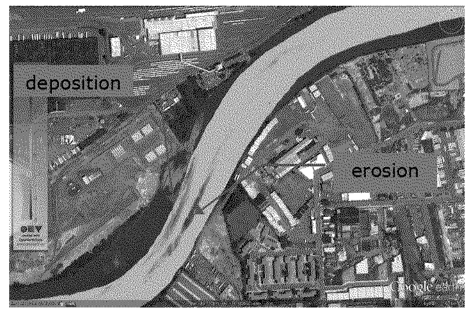


irregular river bank may induce large turbulence and erosion during floods

bed level changes RM 3.5 – 4

seems cyclic

2007 to 2008_corr
(no major river flood)



2008_corr to 2010
(2010 river flood)

infill after flood – role of eddies etc.

bed level changes RM 3.5 – 4

2008_corr to 2010
(2010 river flood)

2010 to 2011_post
(two 2011 river floods)

Similar erosion patterns for both floods.
Pattern shifted downstream for 2011 floods.

bed level changes RM 3.5 – 4

2010 to 2011_post
(two 2011 river floods)

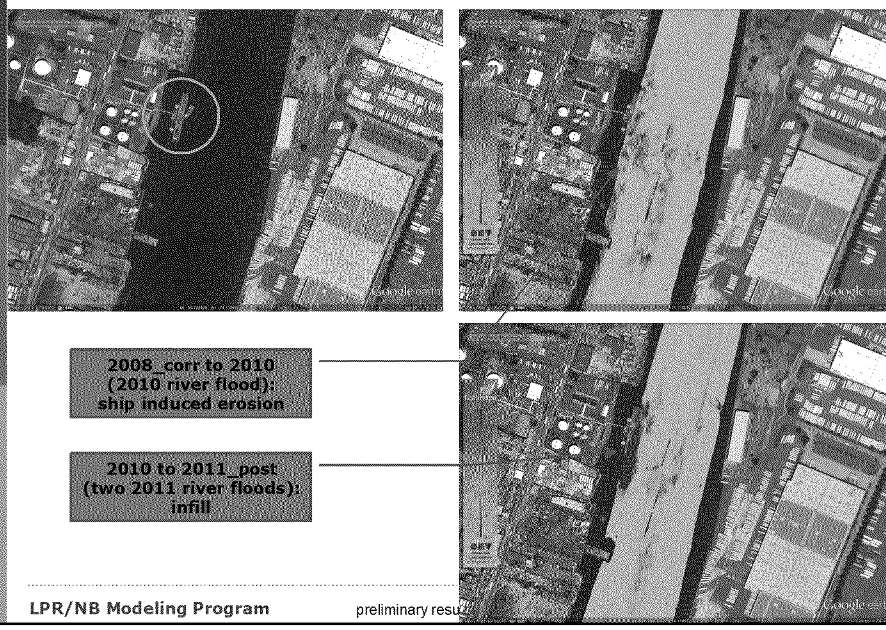
computed skin friction
(24000 cfs ~ Irene flood)

Locations with high skin friction (yellow: 20-30 dynes/cm^2 = 2-3 Pa) do not coincide with location showing major erosion (dark blue) (soft bed and/or spiral flow effects?).

Types of local effects:

Effect of Shipping

shipping induced erosion (~RM 1.4)

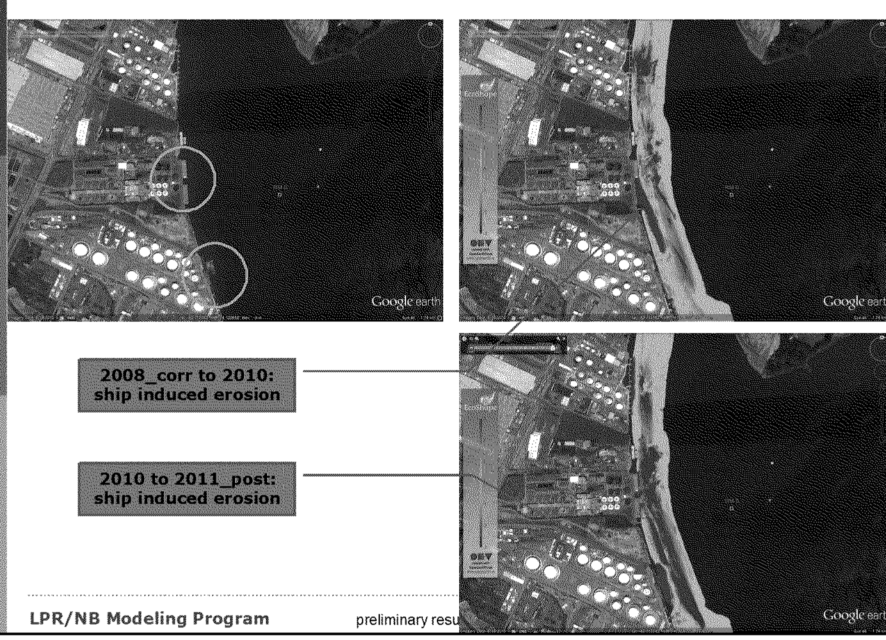


2008_corr to 2010
(2010 river flood):
ship induced erosion

2010 to 2011_post
(two 2011 river floods):
infill

preliminary resu

shipping induced erosion (~RM 0)



2008_corr to 2010:
ship induced erosion

2010 to 2011_post:
ship induced erosion

preliminary resu

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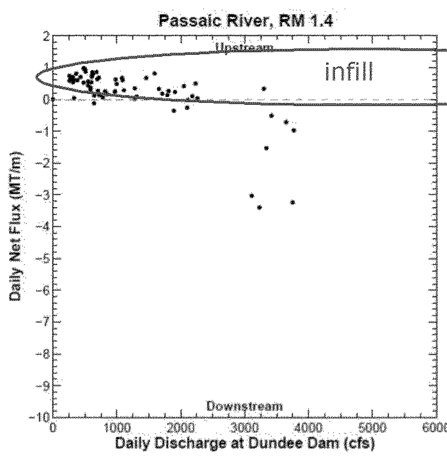
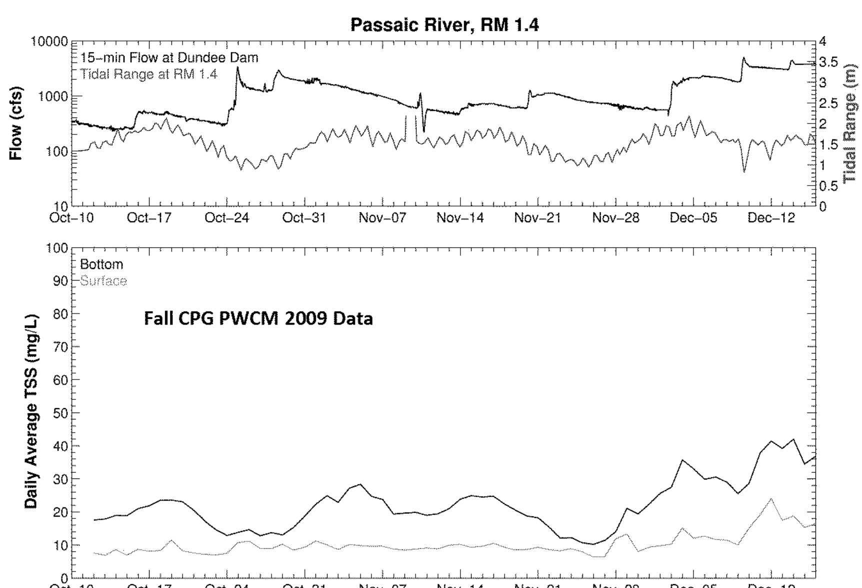
recap on hydro-sedimentological regimes LPR

- Regime I: Sediment accumulation in LPR
- Regime II: Flushing of fluffy sediment
  from TSS-data
- Regime III: Erosion and scour of LPR bed
  from TSS-data & bathymetrical response

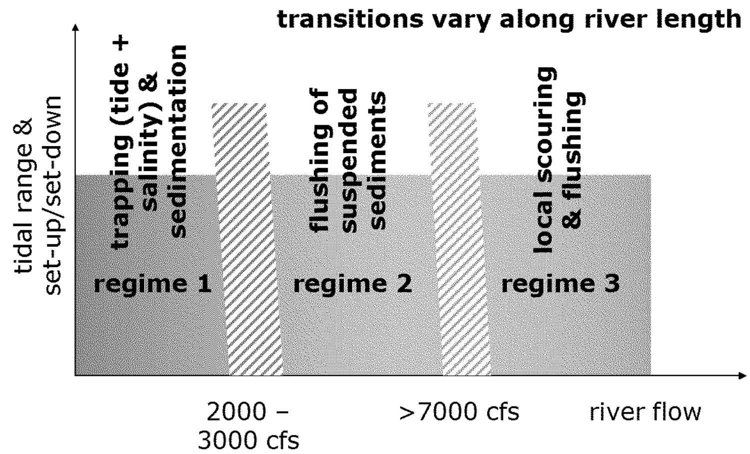
observed import/flushing (Fall 2009 PWCM)



TSS low at river flows up to 6000 cfs



hydro-sedimentological regimes LPR



Conceptual picture now based on detailed analyses and comparison with other rivers

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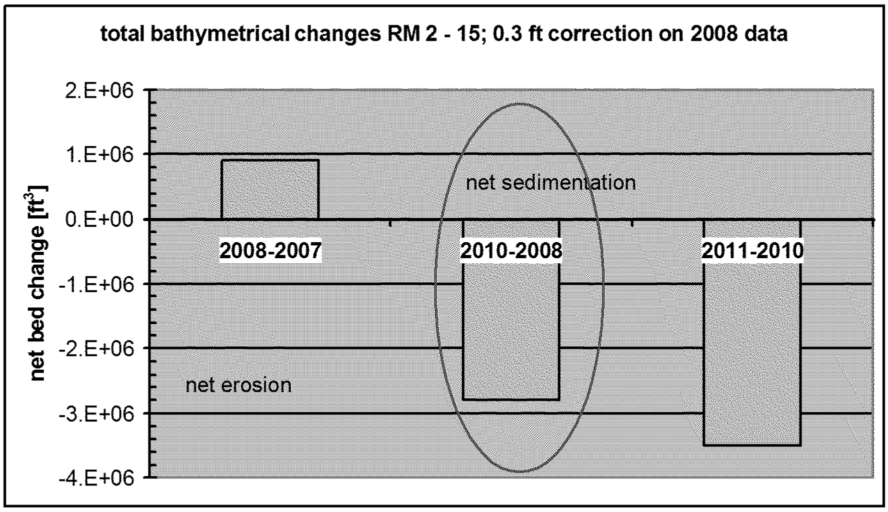
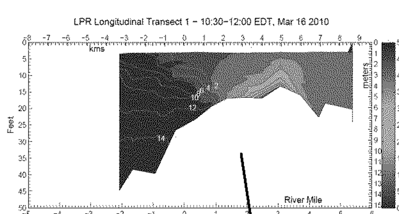
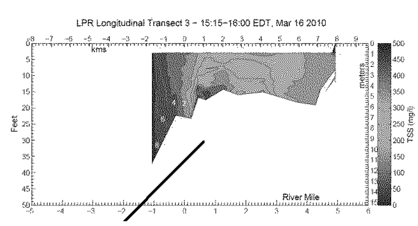
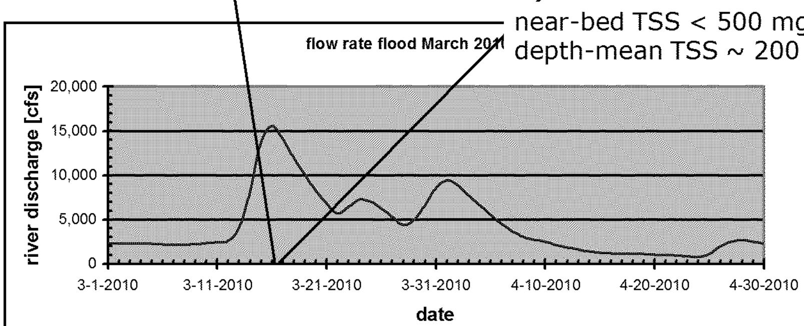


TSS measured during March 2010 flood





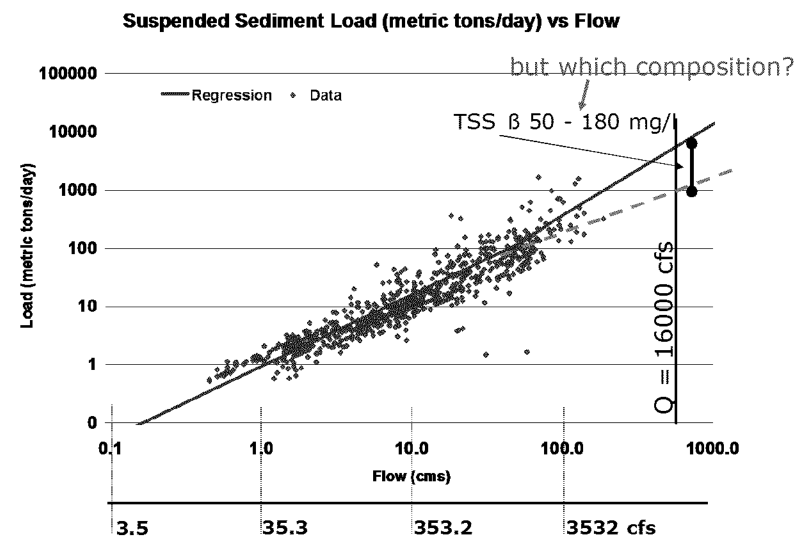
near-bed TSS < 500 mg/l,
depth-mean TSS ~ 200 mg/l



data by Bob Chant

upstream loadings – Dundee Dam

Currently using HQI rating curve



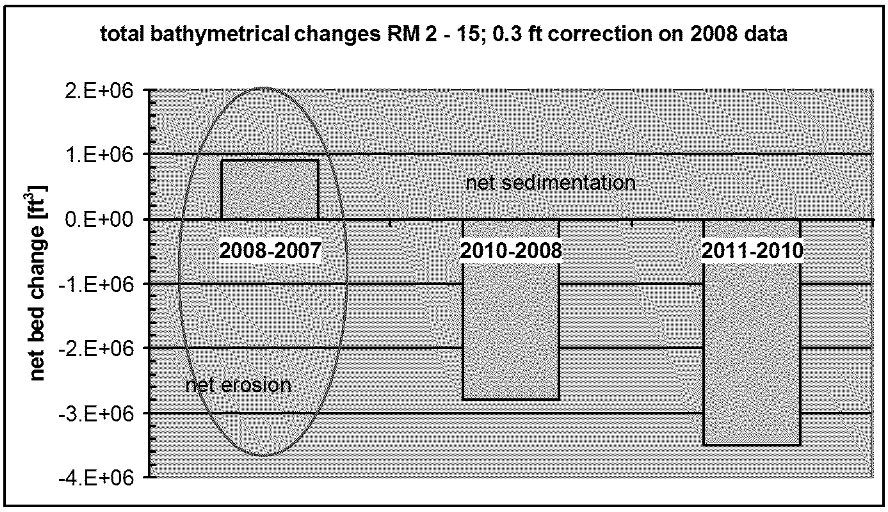
net bed level changes & TSS

- Use 2010-2008 bathy difference
- Take Sedflume bulk densities
- Analyze for March 2010 flood:
  - 2 days flood (day 2, 3, & 4)
  - 8 days flood (> 8,000 cfs)
  - 23 days flood (>4,000 cfs)

	rho_bulk	rho_bulk	
	1200	1400	kg/m3
3 days flood	**234**	**493**	mg/l
8 days flood	**114**	**241**	mg/l
23 days flood	**54**	**114**	mg/l

TSS Chant: ~200 mg/l
Dundee Dam: 50 – 180 mg/l
without 2008 correction we get nonsense

overall mass balance agrees with hydrograph

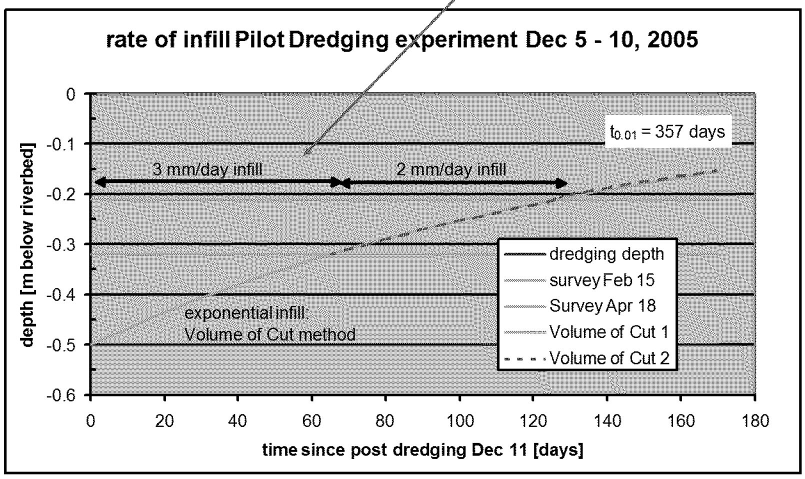


infill during 2007 – 2008 surveys

- net infill TSS data and hydrograph suggest infill between 25-3 and 27-11-2008 (= 245 days)
- net infill data suggest infill at RM1.4 of 0.5 MT/m/day; river width = 120 m, hence 60,000 kg/day
- rating curve Dundee Dam suggests ~100,000 kg/day
- upstream and downstream import comparable
- using bulk bed densities:
  - 1200 kg/m^3: 1.8 + 2.9 = 4.7 Mft^3 infill
  - 1400 kg/m^3: 0.8 + 1.4 = 2.2 Mft^3 infill
- bathymetry 2008 – 2007 suggests ~1 Mft^3 infill
- this suggests more detailed analysis is useful

analysis pilot dredging exp

6000 cfs flood seems to have no effect on infill rate



infill of 3 mm/day implies infill by 1 foot in 109 days

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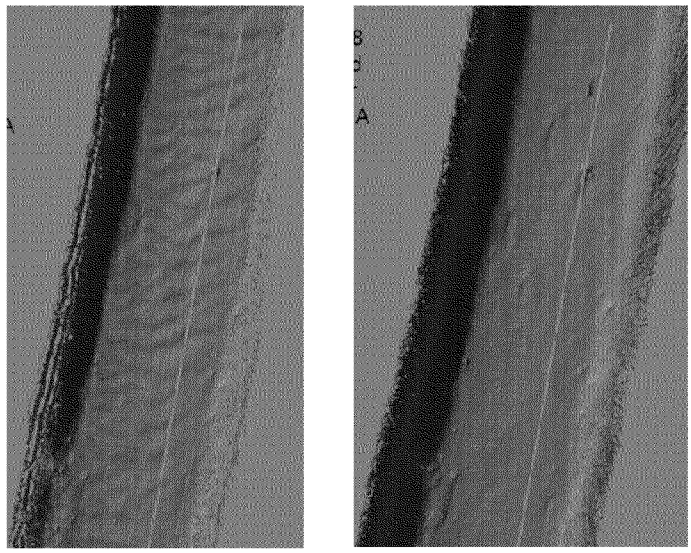
bed forms around RM13.6 (high resolution)

2007 multi-beam survey   2008 multi-beam survey



bed forms around RM 13.6

Longitudinal profile

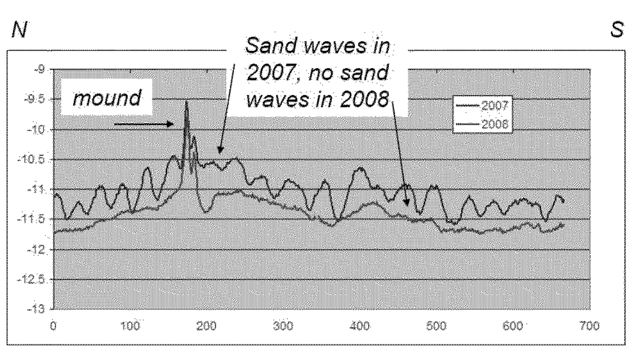


Figure 7c:

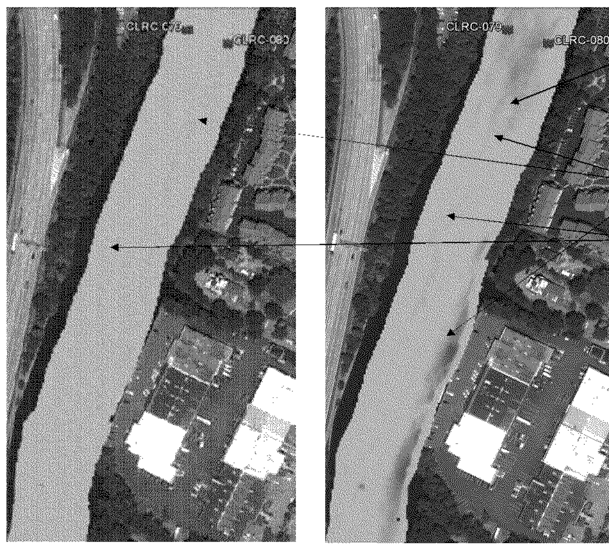
River Segment A (RM13.6) Transect bathymetry in 2007 and 2008 and change (2008-2007).

Depths (x-axis) and Distances (y-axis) in Feet

theory: bed forms form at specific river flows, not when flow is:
- too low as in 2007 – 2008
- too high as in 2011 – 2010

bed forms between RM 13.3 & 13.6

2010 - 2008 | 2011 - 2010



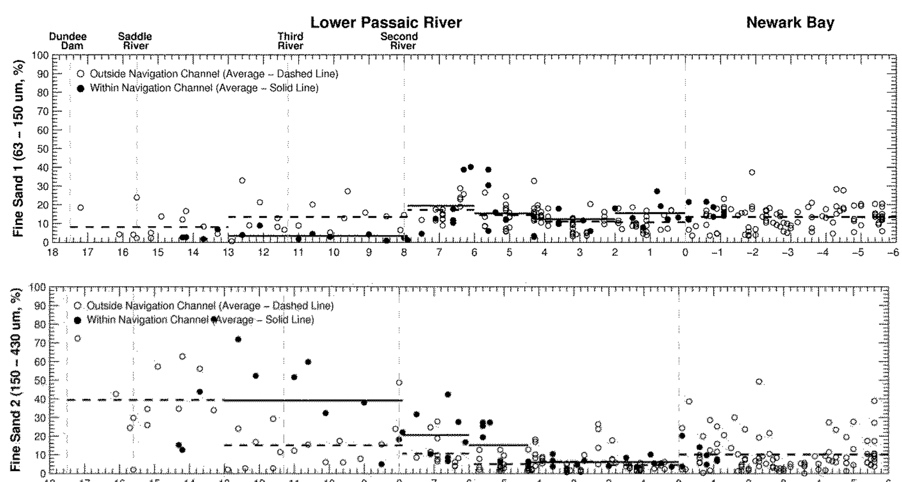
bed forms washed away and buried

1-2 ft infill

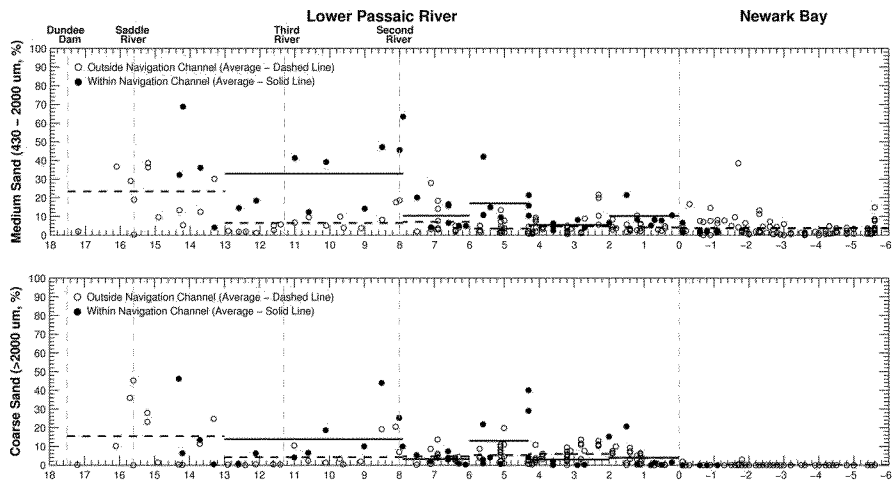
<1 ft erosion

NB here differential maps as 5×5 foot resolution is too low to visualize bed forms properly

grain size distribution – top 6"



grain size distribution – top 6" (contd.)



sand transport

- data show considerable sand transport in upper LPR
- this is reflected in sand content over entire LPR
- sediments scoured around bridge pillars are deposited downstream of scouring places: this must be coarser material as scour occurs under high flow events
- very important for:
  - sand helps to armor the bed against erosion
  - this armoring is at the heart of SEDZLJ modeling

discussion and conclusions (1)

- 2008 multi-beam data is corrected by -0.3 ft
- 2007-2008: net infill, as no events
- 2008-2010: net erosion due to March 2010 flood
- 2010-2011: net erosion due to two floods, including Irene – total erosion rate comparable to 2008-2010
- Erosion/deposition largely (but not only) due to local scour around irregularities (bridge pillars, bank extrusions, ...)
- Erosion-deposition show often cyclic behavior
- This scouring is a sub-grid effect in our models (cannot be resolved in detail)

discussion and conclusions (2)

- 2008 – 2007 bathy infill corresponds to first order of magnitude with sum of net upstream transport (from TSS data) and Dundee Dam import (from rating curve)
- Pilot dredging experiment showed infill rate of ~3 mm/day. i.e. 1 foot in 109 days – hence infill of scour holes within 2008 – 2007 bathy is consistent
- Large changes in bathy & bed forms in upper reaches of LPR are (partly) attributed to transport (bed load) of sand
- The latter is consistent with grain size distribution in lower LPR reaches, and explains armoring (model approach)